A Comparative Study of

The Structure of The Arteries of the

Limbs in The Human Subject

By

Moray Melvin.

September 1933.

CONTENTS.

INTRODUCTION.

The problem of the structure and properties of the arterial wall is an important one to physiologists and pathologists alike. The elastic properties of the arterial wall have been investigated from many points of view by numerous workers, but the relation between the behaviour of the artery and its minute structure has received less careful attention, particularly from workers in this country.

In the course of an investigation into the elasticity of arteries considerable differences were observed between the pulse wave velocity in the arteries of the upper and lower limbs. It was also found, as would be expected, that the pulse wave velocity in the vessels of the arm varied considerably at different age periods. Bramwell, Hill and McSwiney (1923) noted that "as age increases there is a notable decrease in the elasticity of arteries at the actual diastolic pressure of the individual". It seemed desirable therefore to have some precise information as to the minute anatomy of the arteries of the limbs in order to correlate as far as possible these variations in function with differences in structure.

The available literature on this subject was referred to, but no adequate comparative study was found

of the arteries of the upper and lower limbs in man. Although a number of workers have studied the changes in structure of human arteries with age, yet most of these investigations were carried out on arteries not directly related to the investigation of function already referred to. Text books state, merely, that the relative amounts of muscle and elastic tissue vary with the size of the vessel. Different workers have made observations on the structure of particular vessels.

Bonnet (1912), observed that the tunica media not only changes with age but also in one individual from region to region of the arterial system according to the particular function of the vessel and the strains to which it is subjected.

Hiroschi Aihara (1919) described the Brachial Artery of man at ages 24 years and 61 years. Proximally these vessels showed thick elastic fibres, but distally these fibres became fewer and were concentrated in the outer half of the media.

H. M. Turnbull (1915) described the Aorta, Innominate, Subclavian, Common Carotid, Internal and External Carotid Arteries as elastic. He stated that these arteries pass abruptly into those of a muscular type.

L. S. Foster (1909) investigated sections of

the Thoracic and Abdominal Aortas of a large number of subjects from 6 months to 80 years. He noted a progressive development of elastic tissue up to 35 years of age, the whole media increasing with a relative decrease of muscle. In his opinion the formation of new elastic tissue goes on up to 35 years of age. After 50 years, muscle diminishes markedly but no actual loss of elastic tissue was observed during this period, although degenerative changes were noted and the elastic tissue stained irregularly.

Dubreuil, A. Lacoste and C. Margat (1930) described the development of the Arteries in early foetal life and note that the three coats of the arteries are defined at the beginning of the fifth month. The vessels in the series under examination are beyond this age period.

Gimbert (1865) describes the structure of the arteries of both limbs, stating that in the lower limb the media diminishes in thickness as the vessel passes distally whereas in the upper limb the media changes little in thickness from Subclavian to Radial Artery. In the Axillary and Brachial Arteries, he states, that as the vessels pass downwards they show more muscle while the elastic tissue decreases.

N. Grunstein (1896) examined a number of subjects ranging from the newly born to 70 years of age.

He described the Subclavian Artery and the lower part of the Common Iliac Artery.

A considerable amount of work has been done on the detailed structure of the various constituent elements of the arterial wall. Bonnet (1912) describes the form and arrangement of the elastic fibres in the media. Dubreuil, Escudier and Donnadieu (1929) describe the structure and variations of the external elastic lamina while Wolff (1928) describes the structure and variations of the internal elastic lamina.

Dubreuil and A. Lacoste (1930) describe the development of the elastic layers of the arterial system. The development of internal and external elastic laminae are described. The elastic lamellae of the media appear first as fine fibres in a delicate network of connective tissue at the outer part of the media. Gradually these fibres increase and enlarge until they are arranged in layers. During the next stage these layers of fibres form continuous lamellae while the muscle cells begin to appear between.

A. Ssolowjew (1923) describes a chromotrope substance between the elastic and muscle fibres. He states that this substance is connected with elastic tissue, being found not only in contact with the fibres but also filling the splits in the lamellae. It is a normal constituent of the vessel wall.

No attempt has been made in the investigation presented to deal with these morphological problems.

Many workers have examined the arteries of animals and certain of the conclusions reached are applicable to human vessels, e.g. Baum and Thienal (1904) compared the Axillary Arteries in a large number of animals. They noted the different arrangement of elastic tissue in the different animals examined and that the development of muscle varies in the different animals. They also noted the thickening of the arterial wall before a branch is given off and that this thickening involved mainly the media. At this point both muscle and elastic fibres tend to run longitudinally and spirally. The increased thickening of the intima with age noted by Ebner was not confirmed.

The object of the investigation here presented was to make clear the distribution and relative proportions of the elastic elements of the arterial wall (i.e. smooth muscle and elastic tissue) rather than to study the constitution of the elements. In order to do this it is essential to accept and follow some definition of the various parts of the arterial wall. There is not complete agreement between different writers as to the delimitations of these various parts. Bonnet for example includes everything from endothelium to external elastic lamina as tunica media, not making the internal elastic lamina the boundary between intima and media.

The general scheme adopted as a basis for description in the present investigation was that suggested by Schiefferdecker and quoted by Grunstein (1896). It may be summarised as follows, the vessel wall being divided into three coats:-

Vessel Wall. Endothelium.

Accessoria:- I. Tunica Intima. (i) Subendothelial.

(ii) Elastica Interna.

II. Tunica Media. (i) Muscle.

(ii) Elastic Tissue.

(a) Concentric fibres or net work.

(b) Concentric lamellae.

(c) Connecting fibres, long;oblique,radial.

(iii) Connective tissue.

(a) Subelasticum.

(b) Submuscular.

(c) Intermusculares.

III. Tunica Adventitia.

(i) Elastica externa.

(ii) Stratum Elasticum.

(iii) " " Long:

Circ:

This investigation is confined to the structure of the Tunica Media with special reference to the relative amounts of muscle and elastic tissue.

METHODS.

The arteries were taken from the subjects as soon after death as possible, and never later than twenty-four hours. In the case of foetal vessels some times two or three days elapsed before the arteries were obtained.

The subjects selected were as nearly normal as possible, cases of prolonged illness being avoided. The previous history, cause of death, state of cardio-vascular system at post mortem, and age were ascertained. Subjects with obvious arterial disease post-mortem, or with a history suggestive of such change were discarded.

The Arteries taken were the Axillary Artery at its mid point; the Brachial Artery just before its bifurcation at the elbow, and the Radial Artery at the wrist.

In the leg the Femoral Artery was taken just below Poupart's Ligament; the Poplitial Artery behind the knee joint, and the Anterior Tibial Artery in front of the Ankle joint.

The vessels were fixed with no special regard to their state of contraction. They were fixed in

formalin and embedded in paraffin in the usual way. A. H. Mackie and J. H. MacWilliam (1908) discuss the contraction of arteries and methods of preventing contraction. They state that after protracted illness, Arteries are usually relaxed after death, but after sudden death are often strongly contracted. There is a great difference found in the size of the lumen and the thickness of the walls depending on whether vessels have been treated or not. The degree of waviness of the internal elastic lamina is a useful indication of the state of contraction of the vessel. In the majority of the sections presented here, the internal elastic lamina has a markedly wavy outline.

The sections were cut at a thickness of between 5 μ and 10 μ.

All the sections are transverse as this section shows the relative amounts of muscle and elastic tissue in the tunica media.

Methods of Staining.

As a routine stain Weigert's Elastic Tissue Stain was used with Picric Acid as a counter stain, (following the method of Pfister Ines (1927)). This stain shows the distribution and the arrangement of the elastic tissue.

Iron Haematoxylin and Van Gieson's Picro saure-fuchsin were used as alternatives in order to show the

arrangement of muscle and connective tissue. This method of staining was used for demonstrating the increase of connective tissue and the changes in the muscle tissue which occur in most arteries during later life.

Examination of Sections.

The sections examined were classified as being Elastic, Musculo-elastic and Muscular. The term Elastic was applied to those arteries which showed a predominance of elastic tissue arranged in concentric lamellae through the media. The term Musculo-Elastic was applied to those vessels where the Muscle and Elastic tissue were approximately equal in amount, the elastic tissue being mainly in the form of thick and fine fibres.

The term Muscular was applied to those vessels where the muscle predominated although these vessels usually contained fine elastic fibres.

The Elastic Tissue was described as complete lamellae, or fibres, thick, medium and fine.

Arteries from subjects of ages ranging from foetal life to age 76 years were selected according to the conditions already stated. Arteries were taken from nine foetuses (ages 20 weeks, 32 weeks, 38 weeks and full term), and from twelve subjects whose ages ranged from 8 months to 76 years.

(The post natal ages were 8 months, 2 years, 6 years, 8 years, 18 years, 19 years, 28 years, 48 years, 54 years, 58 years, 67 years, and 76 years).

Sections were made of the arteries taken from the subjects enumerated above and examined microscopically. The structure of the tunica media in each vessel was described in order to form a basis of comparison between the vessels (a) in different parts of the limbs and (b) at different ages.

To facilitate the comparison of vessels at the various age periods, the arteries from the subject age 18 years have been chosen for detailed description and will be used as a base line for comparison. This age was chosen to represent a period of complete development of the vessel wall without any of the regressive changes which appear later.

Subjects at certain age periods have been selected for photography and detailed description. The selection represents the changes occurring throughout the whole range, and is presented in Volume II.

Description of Arteries.

Description of the Arteries of the Subject at 18 years.

The Axillary Artery is a very elastic vessel. The tunica media contains a number of elastic lamellae and many thick and medium elastic fibres with small areas of muscle between them. There is no well defined

limit to the media as it merges into the adventitia.

The Brachial Artery is very much less elastic, and the elastic tissue in the form of fine and medium fibres is mainly concentrated in the inner half of the media, giving the appearance of two zones, an outer muscular and an inner elastic. This feature of the Brachial Artery is constant and is better demonstrated in the subjects at 6 years and 19 years. The Brachial Artery is a musculo-elastic vessel.

The Radial Artery is of the muscular type, but it shows many fine elastic fibres evenly distributed throughout the media with an occasional medium fibre.

Comparison of Arteries of Arm in subject aged 18 yrs.

There is a marked difference in content of Elastic tissue between the Axillary and Radial Arteries. The Brachial Artery is intermediate between them in structure although in this subject it approaches more nearly the structure of the Radial Artery.

The Femoral Artery is a musculo-elastic vessel. The elastic fibres are of fine and medium thickness and are fairly evenly distributed throughout the media. There is a tendency for the elastic tissue to be more concentrated in the inner half of the media although this is not so marked as in the Brachial Artery.

The Popliteal Artery is very much less elastic than the Femoral Artery. The elastic fibres are of a

fine and medium character and are more marked in the inner half of the media, giving that appearance of two zones so well marked in the Brachial Artery.

The Anterior Tibial Artery is a muscular vessel showing an even distribution of fine elastic fibres throughout the media with an occasional medium fibre.

Comparison of Arteries of Leg in Subject aged 18 years.

The difference in elastic tissue content between the Femoral and Anterior Tibial Arteries is much less marked than that between the Axillary and Radial Arteries. The Popliteal Artery is intermediate in structure between the Femoral and Anterior Tibial Arteries.

Arteries of Arm and Leg of Subject aged 18 yrs.compared.

The Axillary Artery is much more elastic than the Femoral Artery. The Brachial Artery and the Popliteal Artery show a great similarity in elastic tissue content. The Radial Artery is slightly more elastic than the Anterior Tibial Artery. The range of variation in the structure of the media is therefore much greater in the arteries of the arm than in those of the leg.

Foetal Arteries.

The Axillary Artery in the foetus at the ages examined is very elastic. The media is packed with elastic lamellae. There is a small amount of

cellular tissue between the lamellae, but no bundles of muscular tissue such as are seen in the artery at the age of 18 years.

The Foetal Brachial Arteries are musculo-elastic vessels. At 20 weeks the muscular tissue predominates while near full term the elastic tissue and muscular tissue are evenly proportioned. Most of the elastic fibres are of medium thickness with a few fine fibres. There is no division of the media into the two zones seen in the post natal Brachials.

The Foetal Radial Arteries at 20 weeks are muscular showing a few medium fibres and numerous fine elastic fibres in the media. The Radials at full term are distinctly musculo-elastic showing many medium and fine elastic fibres.

The Foetal Femoral Arteries are musculo-elastic, the muscular tissue predominating at 20 weeks while at full term the elastic tissue predominates.

The Foetal Popliteal Arteries are similar to the Femorals but are less elastic.

The Foetal Anterior Tibial Arteries are very similar to the Radials being musculo-elastic at full term, and muscular at 20 weeks.

Post-Natal Arteries.

The Subject at age 8 months.

The Axillary Artery at 8 months is a very elas-

tic vessel. The media is packed with elastic lamellae, there being only small evidence of muscle fibres between. It is distinctly more elastic than the artery at 18 years.

The Brachial Artery at 8 months is musculo-elastic showing the two zones characteristic of this artery. This vessel shows more elastic tissue than the artery at 18 years, the elastic tissue being in the form of medium and fine fibres.

The Radial Artery is a muscular vessel. Only an occasional medium and a number of fine elastic fibres are seen. The vessel at this age is relatively less elastic than at birth and at 18 years.

The Femoral Artery at 8 months is musculo-elastic, the elastic tissue being in the form of fine and medium fibres, and is chiefly concentrated in the inner zone. There is relatively less elastic tissue present than in the artery at 18 years.

The Popliteal Artery at 8 months is very similar in appearance to the Femoral. It is less elastic and there is more concentration of the elastic tissue in the inner half of the media, giving the two zone appearance of the Brachial Artery. It resembles the Popliteal Artery at 18 years.

The Anterior Tibial Artery at 8 months is a muscular vessel. There are many fine elastic fibres

to be seen and a few medium fibres. It is less elastic than the artery at 18 years.

The Subject at age 8 years.

At 8 years the Axillary Artery continues to be a very elastic vessel. Elastic lamellae pack the media, very few muscle fibres being seen. It is still relatively more elastic than the artery at 18 years.

The Brachial Artery is musculo-elastic. The elastic tissue is in the form of fine and medium fibres which are concentrated chiefly in the inner half of the media, the outer half being mainly muscular. It resembles the artery at 18 years, but it is relatively more elastic.

The Radial Artery is muscular. There are many fine and a few medium elastic fibres present. It is less elastic than the artery at 18 years, and more elastic than the artery at 8 months.

The Femoral Artery is musculo-elastic and similar in appearance to the artery at 18 years.

The Popliteal Artery shows fewer elastic fibres than the Femoral and resembles the artery at 18 years.

The Anterior Tibial Artery is muscular and shows many fine and a few medium elastic fibres evenly distributed throughout the media. It is more elastic than at 8 months and as elastic as at 18 yrs.

The Subject at age 28 years.

At this age the Axillary Artery is still an elastic vessel. The media shows a number of elastic lamellae and many medium and fine elastic fibres but the areas of muscle are greater in extent than in the artery at 18 years.

The Brachial Artery is musculo-elastic, the fibres being of medium and fine character and chiefly concentrated in the inner half of the media. It is relatively less elastic than the artery at 18 years.

The Radial Artery shows many fine and medium fibres throughout the media. The Artery is much more elastic than at 18 years and is almost as elastic as the Brachial at 28 years.

The Femoral Artery shows elastic tissue in the form of fine and medium fibres chiefly concentrated in the inner half of the media but it is less elastic than at 18 years.

The Popliteal Artery shows fine elastic fibres in the inner half of the media, but there is breaking down of elastic tissue and replacement by connective tissue. It is less elastic than the artery at 18 yrs.

The Anterior Tibial Artery shows many fine elastic fibres with an occasional medium one. There is an increase in the connective tissue element but the vessel resembles the artery at 18 years in elastic

tissue content. It is more elastic than the Popliteal Artery at 28 years.

The Subject at age 48 years.

The Axillary Artery is still an elastic vessel. There are thick lamellae present but there is evidence of connective tissue replacing some of the elastic tissue. It is definitely less elastic than the artery at 18 years. There are considerable areas of muscle in the outer half of the media and the elastic tissue is chiefly in the inner half as in the Brachial Artery.

The Brachial Artery although still musculo-elastic in character is less elastic than the artery at 18 years. The two zones are still apparent, but there is some replacement of the elastic fibres by connective tissue.

The Radial Artery although mainly muscular shows much elastic tissue in the form of fine and medium fibres evenly distributed throughout the media. It is much more elastic than the artery at 18 years.

The Femoral Artery does not show much elastic tissue. There is much connective tissue which from its arrangement appears to have replaced elastic tissue fibres. Compared with the artery at 18 years, the Femoral Artery is much less elastic and shows marked signs of connective tissue replacement.

The Popliteal Artery shows very little elastic tissue and resembles the Femoral in the connective tissue replacement. The elastic tissue stain is taken up irregularly.

The Anterior Tibial Artery shows a number of fine elastic fibres evenly distributed throughout the media, and an occasional medium fibre. It contains relatively the same amount of elastic tissue as the artery at 18 years.

The Subject at age 58 years.

The Axillary Artery shows marked evidence of degeneration of the elastic fibres, the stain being taken up irregularly. Connective tissue replacement is very evident and the vessel is much less elastic than the artery at 18 years. The elastic fibres are thinner and concentrated in the inner half of the media.

The Brachial Artery also shows replacement of much of its elastic tissue by connective tissue. The elastic fibres are medium and fine in character. Owing to degeneration the artery is less elastic than at 18 years.

The Radial Artery shows many fine and medium fibres throughout the media. It is more elastic than the artery at 18 years. There is some evidence of connective tissue replacement and breaking down of elastic tissue.

The Femoral Artery shows very little elastic tissue and much connective tissue. The elastic tissue is chiefly in the form of fine fibres with an occasional medium fibre.

The Popliteal Artery shows even more evidence of connective tissue replacement. There is practically no elastic tissue to be seen.

The Anterior Tibial Artery shows only a few fine elastic fibres and there is considerable evidence of connective tissue replacement.

Individual Arteries followed from Early Foetal to Late Life.

Axillary Artery.

From early to late foetal life (20 weeks, 31 weeks, 38 weeks, 40 weeks) this artery is almost completely elastic, the lamellae being of medium thickness with only a small amount of muscular tissue lying between them. Between full term and eight years (8 months, 2 years, 6 years) the vessel increases in thickness, the elastic lamellae becoming thicker and the muscle increasing, but there is no change in the proportions of muscle and elastic tissue. From 8 years to 28 years (18 years, 19 years, 28 years) there is a definite increase in muscle tissue. The first evidence of degenerative change appears at 48 years and this change increases up to 76 years. (54 yrs, 58 yrs, 67 yrs, 76 yrs.)

Brachial Artery.

The Brachial Artery is musculo-elastic throughout foetal life, but during the period 20 - 40 weeks of foetal life the elastic tissue increases more rapidly than the muscle, for the vessel is relatively more elastic at full term than at 20 weeks. (20 weeks, 31 weeks, 38 weeks, 40 weeks). After birth the inner half of the media retains this arrangement of elastic tissue but muscle increases in the outer half of the media. (8 months, 2 years, 6 years, 8 years). At six years this leads to a definite zoning of elastic and muscle tissue, the elastic tissue concentrating in the inner half of the media. Between 18 years and 28 years (18 yrs, 19 yrs, 28 yrs) this increase of muscle tissue extends to the inner half of the media, the whole artery containing more muscle, although the zoning is still apparent. There is thus relatively less elastic tissue during this period. At 48 years, degenerative changes first appear and some elastic tissue appears to be replaced by connective tissue. This degeneration is apparent at all ages above 48 years, (54 years, 58 years, 67 years, 76 yrs.) There are evidences of individual variations in the proportion of elastic tissue.

Radial Artery.

During the later months of foetal life elastic tissue in the radial artery develops more rapidly than

muscle, the maximum amount of elastic tissue appearing at full term when the vessel is musculo-elastic in type. Its development thus runs parallel with the foetal brachial arteries (20 weeks, 31 weeks, 38 weeks, 40 weeks). From 8 months to 2 years there is a progressive development of muscular tissue. From this age to 28 years (6 years, 8 years, 18 years, 19 years, 28 years), there is little change except an increase in thickness of elastic fibres. From 48 years onwards the elastic tissue appears to be relatively increased although showing degenerative changes (48 years, 54 years, 58 years, 67 years, 76 years).

Femoral Artery.

The foetal femoral arteries are musculo-elastic throughout, elastic tissue predominating at full term, (20 weeks, 31 weeks, 38 weeks, 40 weeks). This arrangement of elastic tissue continues up to 6 years (8 months, 2 years, 6 years). From this age to 28 years there is a progressive increase of muscle tissue with a relative decrease of elastic tissue (8 years, 18 years, 19 years, 28 years). From 48 years onwards signs of degeneration are present and this becomes more marked with increasing age. There is a notable diminution not only of the relative but of the actual amount of elastic tissue. (48 years, 54 years, 58 years, 67 years, 76 years.)

Popliteal Artery.

At all ages from foetal life up to 18 years, (20 weeks, 31 weeks, 38 weeks, 40 weeks, 8 months, 2 years, 6 years, 8 years, 18 years), the Popliteal Artery resembles the Femoral Artery in the general arrangement of muscle and elastic tissue, although it is less elastic. It differs from the Femoral Artery in showing degenerative changes as early as 28 years. This degeneration, as in the Femoral, is accompanied by actual diminution of elastic tissue. These changes progress with age and at every age are more marked than in the Femoral Artery, (28 years, 48 years, 54 years, 58 years, 67 years, 76 years).

Anterior Tibial Artery.

During early foetal life this vessel is mainly muscular but shows definite elastic elements (20 weeks, 31 weeks). At full term it becomes musculo-elastic, (38 weeks, 40 weeks). From 8 months to 18 years there is a progressive increase in the thickness of the muscle with increasing age, (8 months, 2 years, 6 years, 8 years, 18 years). From 28 years there are signs of degenerative changes similar to those in the Popliteal Artery but much less marked in degree and unaccompanied by the diminution in elastic tissue. In fact. during this age pariod (28 years, 48 years, 54 years, 58 years, 67 years, 76 years) the Anterior

Tibial Artery in some subjects is a musculo-elastic vessel.

The Arteries of the Arm Compared.

The Axillary Arteries are the most elastic at all age periods. As age advances they become more like the Brachial Arteries by the addition of muscular tissue.

The Brachial Arteries show little change throughout the age periods under review, maintaining their characteristic structure.

The Radial Arteries alter greatly with the advance of years. At first, showing only a very few short fine elastic fibres, they continue to show increased elasticity with each advance in years and show great elasticity at 48 years and 58 years with only few degenerative changes.

Arteries of Leg Compared.

The Femoral Arteries are the most elastic at all ages. The Popliteal Arteries, although similar to the Femorals, are less elastic. The Anterior Tibial Arteries, show little elastic tissue in the early years, but as age advances there is a marked increase in elasticity.

The Arteries of the Arm and Leg Compared.

The Arteries of the arm are on the whole more

elastic in type than those of the leg although the difference between the Axillary Artery and the Radial Artery is much greater than between the Femoral and Anterior Tibial Arteries. This difference becomes less marked with the advance of years, for as the Axillary and Femoral Arteries become relatively less elastic, the Radial and Anterior Tibial Arteries become relatively more elastic.

Degeneration of elastic tissue and replacement by connective tissue appears at an earlier age in the lower than in the upper limb and is always more advanced in the former. With the appearance of degenerative changes in the Axillary and Femoral Arteries is a concomitant increase of elastic tissue in the Radial and Anterior Tibial vessels.

DISCUSSION.

Consideration of the material already described will show that sufficient evidence has been collected to emphasise certain differences in structure between Arteries of corresponding size and position in the arm and leg. Conclusions can be the more definitely drawn since direct comparison can be made between the different arteries in a single subject. When we come to compare the same artery at different ages the range of individual variation becomes very important.

With the small number of subjects available for this investigation, it is impossible to draw definite conclusions, yet sufficient evidence has been obtained to warrant certain generalisations.

In order to be certain of the changes which take place a large number of subjects at each age period ought to be examined.

The conclusions arrived at are not all in agreement with those of other workers on this subject.

Hiroschi Aihara (1919) states that the Brachial Artery at ages 24 years and 61 years contains much elastic tissue at its proximal end and when traced distally the elastic tissue is packed in the outer half of the media, the inner half becoming more muscular.

All the sections of the Brachial Artery examined in this investigation showed in some degree a division of the media into two zones, an outer mainly muscular and an inner more elastic zone resembling the structure of the Axillary Artery. The inference from this is that muscle increases in the outer half of the media as the artery is followed distally whereas Aihara considers that the reverse is the case.

Hiroschi Aihara also states that the External Iliac Artery at 18 years was entirely muscular from its origin. The Femoral Artery at 18 years in this investigation was distinctly musculo-elastic.

With regard to the Femoral Artery, Gimbert (1865) states that the outer half of the media contains many muscle fibres, and the inner half contains few muscle fibres in a network of elastic fibres. The latter finding is in agreement with the results of this investigation.

Gimbert also states that the Popliteal Artery at its extremity is mainly muscular and from here downwards elastic lamellae practically disappear and that the Anterior Tibial Artery is entirely muscular. The Popliteal and Anterior Tibial Arteries examined in this investigation show more elastic tissue than is suggested by Gimbert, and the Anterior Tibial Artery is by no means entirely muscular, there being many

fine elastic fibres and even medium fibres to be seen.

In the Arm Gimbert describes the Axillary and Brachial Arteries as containing few and fine elastic lamellae, the muscle tissue holding an important place. The Axillary and Brachial Arteries examined here are notable for their large elastic tissue content, the Axillary Artery at all ages showing many thick lamellae while the Brachial Artery up to early adult life contains many elastic fibres.

Gimbert notes that the arteries of the arm and leg are characterised by the gradualness of the change from the elastic to the more muscular state, this gradual change being more marked in the arteries of the arm than in those of the leg. This investigation supports that observation.

With regard to the development of elastic and muscle tissue, N. Grunstein (1896) examined the Subclavian Artery at birth, at 16 years, 50 years and 70 years. At birth he described it as elastic, while at 16 years he noted a layer of muscle fibres in the inner half of the media. At 50 years he found it elastic with muscle fibres in the inner part of the media and he noted some degeneration of the elastic tissue. At 70 years he found the Sub-

clavian to be an elastic vessel with some degeneration of the elastic lamellae. These observations indicate that no new elastic lamellae were laid down after birth but that new muscle tissue continued to develop up to adult life.

Examination of the Axillary Arteries in this series shows that the proportion of elastic tissue and muscle undergoes variations with age similar to those described by Grunstein, but with this important difference that the newly formed muscle appears in the outer part of the media leaving the inner zone the more elastic.

N. Grunstein also examined the lower end of the Common Iliac Artery at birth, 16 years, 30-40 years, 50 years, and 70 years. He states that the Artery is elastic at birth and musculo-elastic at 16 years. He notes little change from 16 years onwards and states that even at 70 years no degenerative changes were seen. These observations confirm the conclusions inferred from Grunstein's examination of the Subclavian Artery, namely that the full number of elastic lamellae are present at birth but that new muscle fibres appear up to 16 years.

Thoma and Kaefer (1888) in discussing their reasons for experimenting with the External Iliac Artery state that degenerative changes are most

frequent and earliest in this vessel.

The present investigation indicates that degenerative changes in the media occur at an earlier age in the arteries of the lower limb than in those of the upper limb, and at any age these changes are more advanced in the vessels of the leg. This is in direct contradiction to Grunstein's findings.

L. S. Foster (1909) examined the Thoracic and Abdominal Aortas of subjects from six months to 80 years. He noted that up to 4 years there were very few fine elastic fibres between the elastic lamellae, a fact which was observed in this investigation. He states that these fine fibres increase in number and in thickness until at between 20 years and 30 years they are as thick as lamellae. He concludes that there is a progressive development of elastic tissue up to 35 years, during which period there is a relative decrease of muscle tissue. From 35 years to 50 years he states that the production of new elastic tissue ceases and muscle seems to diminish, and after 50 years the muscle diminishes markedly. These statements imply that no new muscle appears after birth, whereas Grunstein describes an increase in muscular tissue up to 16 years of age. Foster states that there is no actual loss of elastic tissue during later life although degenerative changes are seen. At 50 years he notes that the elastic tissue stains irregularly.

The observations made in this investigation disagree in a number of respects with those of the workers quoted. In his observations upon the Subclavian and Common Iliac Arteries Grunstein notes the maximum development of muscle tissue at 18 years whereas in this investigation the maximum development of muscle tissue in the Axillary, Brachial and Femoral Arteries appears to be somewhat later (28 years).

According to Foster not only do elastic lamellae in the Aorta increase in thickness, but also increase in number up to 35 years.

Grunstein on the other hand notes that in the Subclavian and Common Iliac Arteries no new elastic lamellae are laid down after birth.

The observations made in this investigation agree with those of Grunstein that no new elastic lamellae are laid down after birth, but that they increase in thickness. This investigation shows the maximum development of elastic tissue to appear at about 18 years whereas Foster puts it at 35 years. On the other hand, an increase of elastic tissue was found during later life in the Radial and Anterior Tibial Arteries. This increase appeared from 48 years onwards and was due not merely to a decrease in muscle but to the development of elastic fibres.

In his examination of the Subclavian Artery,

Grunstein first noted degenerative changes in the elastic lamellae at 50 years, while in his examination of the lower end of the Common Iliac Artery he found no degenerative changes even at 70 years. Foster states that although in the Aorta there is degeneration of elastic tissue, there is no actual loss of elastic tissue.

The observations in this investigation indicate that degeneration of elastic lamellae in the Axillary, Brachial and Femoral Arteries is first seen at 48 years and in the Popliteal Artery at 28 years. Although signs of degeneration are first seen in the Axillary and Femoral Arteries at the same age period, yet it was noted that these changes were more advanced at all ages in the arteries of the lower limb, and that in the latter these changes were accompanied by a loss of elastic tissue, and its replacement by connective tissue.

With regard to the period of growth of the elastic and muscular components of the media, the conclusions reached from a study of the material available for the present investigation may be stated thus. During the later months of foetal life development of elastic tissue is more marked than is that of muscle. After birth there is a steady increase in both muscular and elastic tissue, an increase however which affects the muscle more than the elastic tissue.

The elastic tissue increase is mainly an increase in the thickness of the lamellae and fibres rather than a production of new elements. This development appears to reach its maximum at about the age of 18 years. A notable exception to this is the apparent new development of elastic tissue in the Radial and Anterior Tibial Arteries during late middle life.

The maximal development of muscular tissue appears to be later than that of elastic tissue, and is reached about the age of 28 years.

Certain changes in the tunica media of arteries from middle age onwards have been described as degenerative. These changes affect both muscular and elastic elements. The elastic tissue loses its clear outlines, stains irregularly, and the elastic tissue elements become more widely separated, producing an appearance of fragmentation of the fibres; ultimately there is a disappearance of elastic tissue. These changes resemble those described by Klotz (1906).

The muscle cells likewise become more widely separated and their muclei disappear. Connective tissue takes the place of the disorganised elastic and muscle tissue.

Hitherto the discussion has been confined to alterations in structure and the term elastic has been used strictly in this sense only. The change in structure however must clearly affect the functional capacity of the vessels involved. It is usually considered that the

elastic large arteries have a function similar to the reservoir action of the aorta and it is likely that this change in structure diminishes the part played by the arteries, thereby throwing additional work on the left side of the heart.

Staining with Van Gieson and Iron Haemotoxylin shows clearly the replacement of muscle and elastic fibres by connective tissue. (See Vol.II, Plates XIX to XXIII.)

Evidences of degeneration of elastic tissue in the Arteries examined appear at a constant period in the vessels of the proximal parts of both limbs. But the Radial and Anterior Tibial Arteries are characterised by increased elastic tissue content at the time when the other arteries of the arm and leg are showing decreased elastic tissue and connective tissue replacement. As age increases there are ultimately degenerative changes to be observed in the elastic and muscular tissue of the Radial and Anterior Tibial Arteries, but there is no actual loss of elastic tissue.

It may be that with decreased elasticity of the proximal vessels, the distal vessels, being subjected to greater pressure, develop their elastic tissue content for a period, and then it in turn degenerates. This would suggest that elastic tissue does develop in the Arteries in post natal life.

It will be noticed that these changes in the medial coat described as degenerative resemble those described in the pathology of disease of the arterial wall. The subjects investigated in this series were free from gross arterial disease at death. Although a comparatively small number of subjects have been examined, the changes noted in the media have been so constant as to make it possible to determine what structure to expect in the limb arteries at various ages. These changes may be regarded as physiological and should assist in defining more clearly the boundary line between physiological and pathological states.

The clinician finds it impossible in many cases to say whether thickening in the arteries of the patient is a normal change to be expected with the advance of years, or whether it is the result of disease. It is suggested that the arteries should be examined microscopically post-mortem and compared with such a series of sections as is presented in Volume II. This comparison with the presumed normal state of affairs plus the clinical observations, would in time accumulate a sufficient body of evidence to assist the clinician in correlating the signs observed at the bedside with the pathological state of the artery.

At present the information gained at the bedside is based almost entirely on an examination of the radial artery at the wrist. The condition of the general arterial system is inferred from the condition of this artery.

This investigation shows very clearly that the radial artery is a most unreliable vessel upon which to base conclusions as to the state of the arterial system as a whole. The radial artery at the wrist may contain much elastic tissue while the other arteries of the limb are in an advanced state of degeneration. The radial artery normal to palpation cannot therefore be taken as an indication of healthy arteries in the proximal part of the limb. On the other hand, a radial artery found to be thickened probably indicates that the other arteries of the limb are in a very advanced degree of degeneration.

These observations show the need for a clear definition of the normal range of alteration with age in the structure of the medial coat of arteries. Until this definition is established the pathology of disease of the arterial wall can not be fully understood.

SUMMARY.

Transverse sections of arteries taken at post mortem from the upper and lower limbs of human subjects of different ages have been examined. The examination was directed specially towards the detection of differences in structure between (I) Arteries of a similar size from different regions of the body, and (II) speciments of the same artery taken from subjects of different ages.

The following conclusions have been reached.

1. The Arteries of the upper limb have on the whole a more elastic media than those of the lower limb.

2. The range of variation in structure is greater in the vessels of the upper than in those of the lower limb, i.e. although the Axillary Artery is structurally much more elastic than the Femoral Artery, the Radial Artery closely resembles the Anterior Tibial Artery in the relative proportions of muscular and elastic tissue in the medial coat.

3. Changes in the structure of the media with age have been followed in each vessel examined. In general it has been found that the most rapid development of elastic tissue occurs during the later months of foetal life. During the early years of post natal life the development of muscular and elastic tissue proceeds at approximately the same rate, while during early adult life development of muscular tissue outruns that of elastic tissue.

In later adult life regressive changes appear, obvious first in the proximal vessels of each limb and apparently accompanied in the early stages by an increase in the elastic element of the distal vessels.

REFERENCES.

Aihara, Hiroschi (1919) Mitt.Med. Fak. Tokyo. XXIII. p.93.

Baum & Thienel (1904) Arch. Mikrosk. Anal. LXIII. p.10.

Bonnet R. (1912) Verh. Anat. Ges.Verslg. Munchen. p.7.

Bramwell J.C., Hill A.V., McSwiney B.S.(1923) Heart X. p.233.

Dubreuil G. , Escudier H. Donnadieu (1929) C.R.Soc.de Biologie c. p.742.

Dubreuil G., Lacoste A. (1930) C.R.Soc.de Biologie CV. p.928.

Dubreuil G., Lacoste A. & Margat C.(1930) C.R.Soc.de Biologie CV p.923

Foster L.S. (1909) J.Med.Res. XXI p.297.

Gimbert (1865) J.de L.Anat e-d-la Physiol II pages 536 & 616.

Grunstein N.(1896) Arch-Mikrosk Anat. XLVII p.583.

Ines, H.C.Pfister (1927) J.Anat.LXI p.213.

Klotz. (1906) J. Exp. Med. VIII p.325.

Mackie A.H. MacMilliam J.H. (1908) B.M.J. II p.1477.

Ssolowjew A. (1923) Arch Path. Anat. CCXLI p.1.

Thoma R & Kaefer N. (1888) Visch Arch. CXVI p.1.

Turnbull H.M. (1915) Quart. J.Med.VIII p.201.

Wolff E.K. (1928) Arch. f.Path.Anal. CCLXX p.37.